2873

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In re Patent Application of:
Masanori Iwasaki

Application No.: 09/265,860 Confirmation No.: 5002

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For: IMAGE PICKUP DEVICE Examiner: David Spector

SUPPLEMENTAL RESPONSE AND SUBMISSION OF CERTIFIED TRANSLATION OF PRIORITY DOCUMENT

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

The Applicant submitted a full and timely response to the Office Action mailed August 18, 2003. In that Response, Applicants indicated that an English language translation of the priority document would be filed shortly after the response was filed, in order to perfect the priority claim. Applicant hereby submits an English language translation of Japanese Application No. 10-065966, filed March 17, 1998.

The above-identified application is entitled to benefit of the filing date of Japanese Application No. 10-065966. This Japanese Application has a priority date of March 17, 1998.

Please take this English language translation into account in the examination of this application and make its consideration of record. If the Examiner has any comments or

suggestions that could place this application in even better form, the Examiner is requested to telephone the undersigned attorney at 202-955-3750.

Respectfully submitted,

Dated: September 17, 2003

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DECLARATION

I, Michio Ogawa, having a business address of Ark Mori Bldg., 28F, No. 12-32, Akasaka 1-chome, Minato-ku, Tokyo, Japan, so solemnly and sincerely declare that I well understand English and Japanese language and that the attached English translation is correct, true and faithful translation of Japanese Patent Application No. H10-065966, filed on March 17, 1998 to be best of my knowledge.

Tokyo, This 29th day of August, 2003,

Michio Ogawa

Michio Ogawa

JAPAN PATENT OFFICE

This is to certify that the annexed is a true copy of the following application as filed with this Office.

Date of Application : March 17, 1998

Application Number : Japanese Patent Application No. Hei-10-065966

Applicant : SONY CORPORATION

Commissioner,
Patent Office:

Issuance No.

[Document Name] Patent Application

[Reference Number] 9800109301

[Filing Date] March 17, 1998

[Addressee] Commissioner of Patent Office

[International Patent Classification] H01N 5/335

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[Title of the Invention]

Image pickup device

[Number of claims] 5

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[Name of document] SPECIFICATION

[Title of the Invention] AN IMAGE PICKUP DEVICE

[Claims]

[Claim 1] An image pickup device, characterized in that a refractive index distribution lens having a refractive index distribution which is substantially proportional to the square of the distance from the optical axis in a cross-section vertical to the optical axis is provided as an imaging lens in the neighborhood of an imaging face of an image pickup element.

[Claim 2] The image pickup device as claimed in claim 1, characterized in that said refractive index distribution lens is adhesively attached to said imaging face of said image pickup element by an organic solvent.

[Claim 3] The image pickup device as claimed in claim 1 or 2, characterized in that an optical thin film for reflecting infrared rays is provided on the light incident face of said refractive index distribution lens.

[Claim 4] The image pickup device as claimed in claim 1, 2, or 3, characterized in that infrared-ray absorption means for absorbing infrared rays is provided at the light incident face side of said refractive index distribution lens.

[Claim 5] The image pickup device as claimed in claim 1, 2, 3, or 4, characterized in that curvature is provided to one or both of the surfaces of said refractive index distribution lens.

[Detailed Description of the Invention]

(0001)

[Technical Field to Which the Invention Belongs]

The present invention relates to an image pickup device comprising an image pickup element and a lens for focusing an image onto the imaging face of the image pickup element.

(0002)

[Prior Art]

Recently, an image pickup device comprising a solid-state image pickup element and a lens for focusing an image onto the imaging face thereof has been applied to a camera. An optical lens having uniform refractive index is generally used as a lens for such an image pickup device as described above.

(0003)

In the image pickup device using the lens having uniform refractive index, an optical distance which is extremely large although it is finite is required between the lens and the solid-state image pickup element in order to converge and focus

(image) refracted light beams onto the imaging face of the solid-state image pickup element. Accordingly, the sum of the thickness of the lens and the imaging distance is needed as the optical distance between a first face (the face at the light incident side) of the lens and the imaging face of the solid-state image pickup element.

(0004)

[PROBLEMS TO BE SOLVED BY THE INVENTION]

In the conventional image pickup device as described above, since the total of the lens thickness and the imaging distance is needed as the optical distance between the lens first face (the incident-side face) and the imaging face of the solid-state image pickup element, it is very difficult to shorten the overall length of the optical system. Therefore, requirements of compact design for the image pickup device and the camera using it have never been satisfied.

(0005)

According to the above-described conventional image pickup device, when a lens holder is used to secure a lens so as to be spaced from the image pickup element at a proper interval while a predetermined positional relationship is kept between the lens and the image pickup element, an error of the positional relationship between the lens and the lens holder and an error of the positional relationship between the lens holder and the solid-state image pickup element may occur as

a fabrication error, and thus it is difficult to reduce the error.

(0006)

The present invention has been implemented to overcome the problem of the conventional image pickup device, and has an object to more shorten the overall length of an image pickup device comprising a lens and an image pickup element, and reduce the error of the positional relationship between the lens and the image pickup element.

(0007)

[MEANS FOR SOLVING THE PROBLEMS]

An image pickup device of Claim 1 is characterized in that a refractive index distribution lens having a refractive index distribution is characterized in that a refractive index distribution lens having a refractive index distribution which is substantially proportional to the square of the distance from the optical axis in a cross-section vertical to the optical axis is provided as an imaging lens in the neighborhood of the imaging face of the image pickup element.

(0008)

According to the image pickup device of Claim 1, since the refractive index distribution lens is used as the lens, an image at infinity which is incident as parallel rays of light from the end face of the lens incident side is imaged on the end face of the lens emission side when the length (thickness)

of the lens is set to a meandering period $P = 0.5\pi + n\pi$ ($n = 0, 1, 2, \ldots$). Accordingly, the image is imaged on the imaging face of the image pickup element located in the neighborhood of the end face of the lens emission side, and thus it is unnecessary to set a large gap between the lens and the image pickup element. Therefore, the length of the optical system can be reduced, and the design of the image pickup device can be improved to be more compact in size and particularly thinner in thickness.

(0009)

Further, the lens can be provided in the neighborhood of the image pickup element, and thus the positional relationship between the image pickup element and the lens can be fixed by adhesion with organic solvent or the like, whereby an error factor causing the positional error of the lens to the image pickup element can be reduced and thus the positioning precision can be enhanced.

(0010)

[EMBODIMENTS OF THE INVENTION]

The image pickup device of the present invention is basically characterized in that a refractive index distribution lens having a refractive index distribution which is substantially proportional to the square of the distance from the optical axis in cross-section vertical to the optical axis is provided as an imaging lens in the neighborhood of the

imaging face of an image pickup element. The lens length is preferably set to a meandering period $P = 0.5\pi + n\pi$ ($n = 0, 1, 2, \ldots$). Particularly, it is preferable that the lens length is as small as possible (for example, zero) because the lens length can be shortened.

(0011)

The image pickup device of the present invention can be embodied in such a manner that the refractive index distribution lens and the image pickup element are held by a holder to regulate the positional relationship between the refractive index distribution lens and the image pickup element. However, it may be embodied in such a manner that the refractive index distribution lens is directly adhesively attached to the image pickup element. In this case, the positional relationship between the refractive index distribution lens and the image pickup element can be advantageously controlled with extremely high precision if material which has no adverse effect on the lens and the image pickup element is merely selected as adhesive agent.

(0012)

Further, an optical thin film for reflecting infrared rays may be provided at the light incident face of the refractive index distribution lens, or absorption means for absorbing infrared rays may be provided at the light incident face side of the refractive index distribution lens. With this

structure, the infrared rays can be intercepted.

(0013)

Further, a lens which is provided with a curvature at one end face side or both the end face sides thereof may be used as the refractive index distribution lens. In this case, the optical characteristic based on the refractive index distribution is naturally varied by the curvature, and the combined optical characteristic of the optical characteristic based on the refractive index distribution and the optical characteristic based on the curvature becomes the optical characteristic of the lens. As described above, the present invention has various modes.

(0014)

[Embodiments]

A preferred embodiment according to the present invention will be described hereunder with reference to the accompanying drawings. Fig. 1 is a cross-sectional view showing an embodiment of an image pickup device according to the present invention. In Fig. 1, reference numeral 1 represents a refractive index distribution lens, and the refractive index distribution lens 1 is designed in a cylindrical shape and has a refractive index distribution which is substantially proportional to the square of the distance from an optical axis 2 in a cross-section vertical to the optical axis 2. The refractive index distribution lens 1

adheres to an imaging face 5 of a solid-state image pickup element 4 at the end face of the light emission side thereof by thin and transparent adhesive agent 3 formed of organic solvent, for example. Reference numeral 6 represents an infrared-ray cut filter film formed on the light incident face of the refractive index distribution lens 1, and the filter 6 is formed, for example, by deposition and serves to reflect infrared rays.

(0015)

The length Z of the refractive index distribution lens 1 (lens length) is expressed by the following equation when the refractive index distribution constant $\sqrt{A}$= 0.43, the refractive index N on the optical axis (different from "n" in the equation expressing the meandering period P) = 1.658 and the meandering period P = 0.5π (i.e., for n = 0 in the equation of the meandering period P) with respect to the light of the wavelength of 680 nm. In this case, the calculation is made under the condition that the thickness of the adhesive agent 3 is neglected, the emission-side end face of the refractive index distribution lens 1 is brought into direct contact with the imaging face and the existence of the infrared-rays cut filter film 6 (thickness, characteristic) is neglected.

(0016)

Z = meandering period P/refractive index distribution constant $=(0.5\pi t)/\sqrt{A}$ = 3.653 mm. In the above equation, the

lens diameter is set to 1.8 mm, and thus the refractive index distribution lens 1 of this embodiment is optimum to a 1/10-inch image pickup element 4. This is because the length of the diagonal line of the 1/10-inch image pickup element 4 is equal to 1.8 mm. That is, such a lens 1 is provided on a 1/10-inch image pickup element 4 to obtain an image of a diagonal view angle of 100 degrees. Of course, an infrared-ray image can be removed from the image thus obtained because the infrared-ray cut filter 6 is provided.

(0017)

In Fig. 1, the on-axis optical path and the peripheral optical path are shown. Light beams on the on-axis optical path travel in parallel to the optical axis 2 of the lens 1 and are incident to the refractive index distribution lens 1. The incident light beams on the on-axis optical path are converged onto the end face of the emission side of the lens 1 or to a cross-point between the optical axis and the on-axis optical path behind the emission-side end face of the lens 1.

(0018)

Figs. 2 and 3 show MTF (modulation transfer factor) of the optical characteristic obtained at this time. In Fig. 2, the abscissa represents spatial frequency (cycle/mm) and the ordinate represents modulation, and in Fig. 3, the abscissa represents defocusing position (mm) and the ordinate

represents modulation.

(0019)

The above-described image pickup device is an embodiment of the present invention, and the present invention may be embodied in various modes. First, in order to cut infrared rays, infrared rays may be reflected by an infrared-ray cut filter film 6 as shown in the embodiment, or an optical element 7 for absorbing infrared rays may be provided at the light incident face side of the refractive index distribution lens 1 to cut infrared rays as shown in Fig. 4.

(0020)

As shown in Figs. 5A to 5C, a lens provided with curvature at both or one of the light incident face and the light emission face thereof (as indicated by reference numerals la, lb, lc in Figs. 5A to 5C) may be used as the refractive index distribution lens 1.

(0021)

In this case, the combined optical characteristic of the optical characteristic based on the refractive index distribution and the optical characteristic based on the curvature becomes the characteristic of the refractive index distribution lens 1. That is, one or both of the end faces (surfaces) of the refractive index distribution lens is provided with curvature, and thus the lens effect can be also obtained by the curvature. Accordingly, the same lens effect

can be achieved with a thinner refractive index distribution lens by the total effect of the lens effect based on the refractive index distribution and the lens effect based on the curvature.

(0022)

Accordingly, the more compact and thinner design of the image pickup device can be achieved.

(0023)

[EFFECTS OF THE INVENTION]

According to the image pickup device of Claim 1, a single refractive index distribution lens having a refractive index distribution which is substantially proportional to the square of the distance from the optical axis in a cross-section vertical to the optical axis is used as an imaging lens, so that an image at infinity which is incident from a lens incident-side end face as parallel rays of light can be imaged (focused) on the end face of the light emission side of the lens when the length (thickness) of the lens is set to a meandering period $P = 0.5\pi + n\pi$ $(n = 0, 1, 2, \ldots)$. Accordingly, the imaging face of the image pickup element can be positioned in the neighborhood of the refractive index distribution lens, and it is unnecessary to provide a gap between the lens and the image pickup element. Accordingly, the length of the optical system can be shortened, and the miniaturization of the image pickup device can be achieved.

(0024)

According to the image pickup device of Claim 2, the refractive index distribution lens is adhesively attached in the neighborhood of the imaging face of the image pickup element by adhesive agent, whereby the error factor in association with the positioning between the refractive index distribution lens and the image pickup element is reduced and thus the positioning can be performed with extremely high precision.

(0025)

According to the image pickup device of Claim 3, the optical thin film for reflecting infrared rays is provided to the light incident face of the refractive index distribution lens, whereby infrared rays which are about to enter to the lens are reflected by the thin film to thereby prevent incidence of infrared rays into the image pickup element.

(0026)

According to the image pickup device of Claim 4, the optical element for absorbing infrared rays is provided to the light incident face side of the refractive index distribution lens, whereby infrared rays which are about to enter the lens are absorbed by the element to thereby prevent incidence of infrared rays into the image pickup element.

(0027)

According to the image pickup device of Claim 5, one or both of the end faces (surfaces) of the refractive index

distribution lens is provided with curvature, and thus the lens effect can be also obtained by the curvature. Accordingly, the same lens effect can be obtained with a thinner refractive index distribution lens by the total effect of the lens effect based on the refractive index distribution and the lens effect based on the curvature. Accordingly, the more compact and thinner design can be performed on the image pickup device.

[BRIEF DESCRIPTION OF DRAWINGS]

Fig. 1 is a cross-sectional view showing an embodiment of an image pickup device according to the present invention.

Fig. 2 is a diagram showing the relationship between spatial frequency and modulation of MTF of the optical characteristic obtained by the image pickup device of the present invention.

Fig. 3 is a diagram showing the relationship between defocusing position and modulation of MTF of the optical characteristic obtained by the image pickup device of the present invention.

Fig. 4 is a cross-sectional view showing another embodiment of the image pickup device of the present invention.

Figs. 5A to 5C are cross-sectional views showing various modifications of a refractive index distribution lens of the image pickup device according to the present invention.

[Description of the Reference Numerals and Signs]

1: Refractive index distribution lens

2: Optical axis

3: Adhesive (Organic solvent)

4: Image pickup element

5: Imaging face

6: Infrared-ray cut filter

7: Infrared-ray absorption optical element

[DOCUMENT NAME] DRAWING

FIG. 1

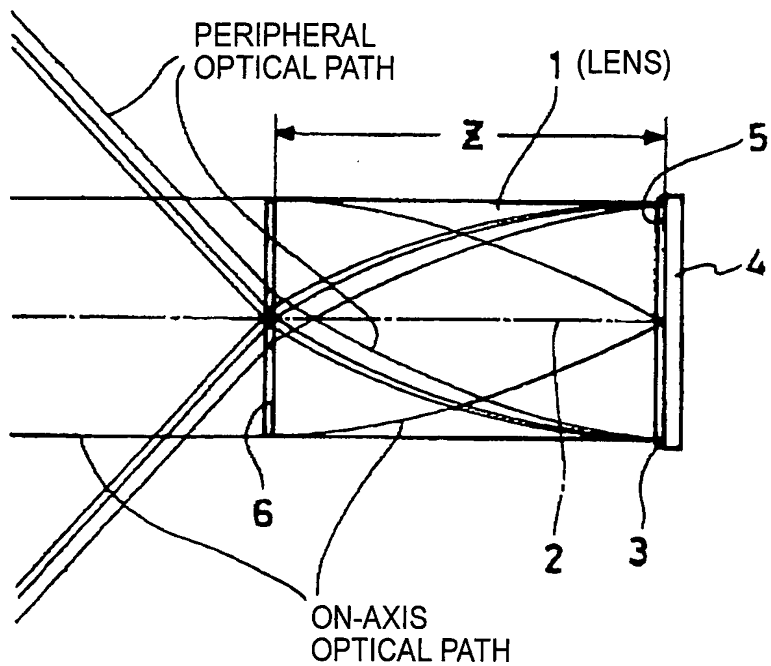


FIG. 2

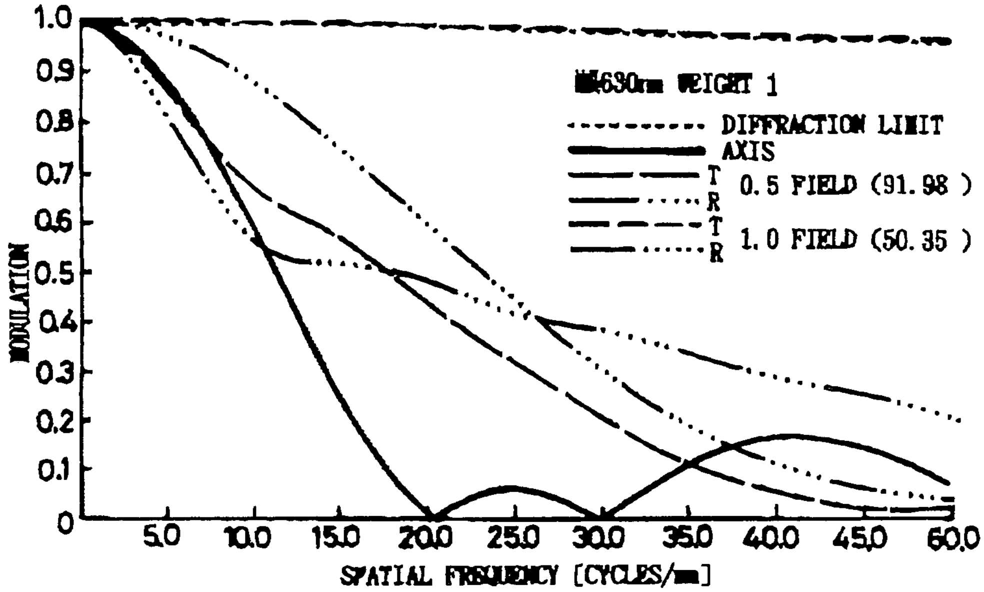

1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
MODULATION
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
60.0
SPATIAL FREQUENCY [CYCLES/mm]
DIFFRACTION LIMIT
AXIS
T
R
0.5 FIELD (91.98)
T
R
1.0 FIELD (50.35)

FIG. 3

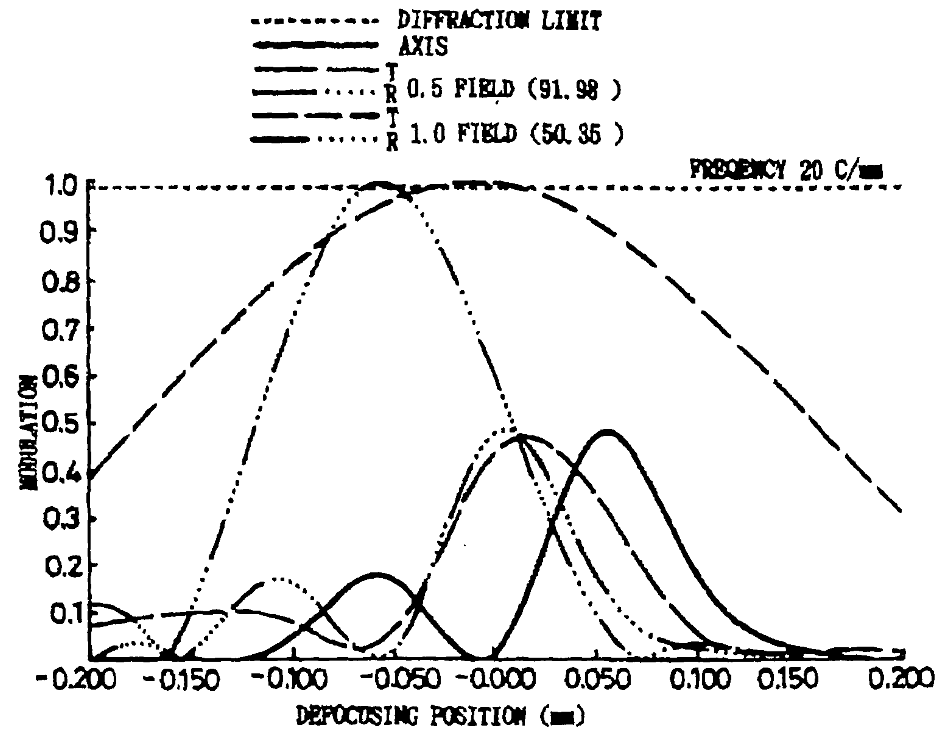

DIFFRACTION LIMIT
AXIS
T
R 0.5 FIELD (91.98)
T
R 1.0 FIELD (50.35)
FREQUENCY 20 C/mm
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
MODULATION
-0.200
-0.150
-0.100
-0.050
-0.000
0.050
0.100
0.150
0.200
DEFOCUSING POSITION (mm)

FIG. 4

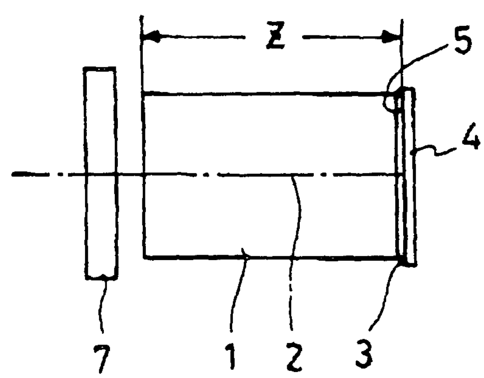
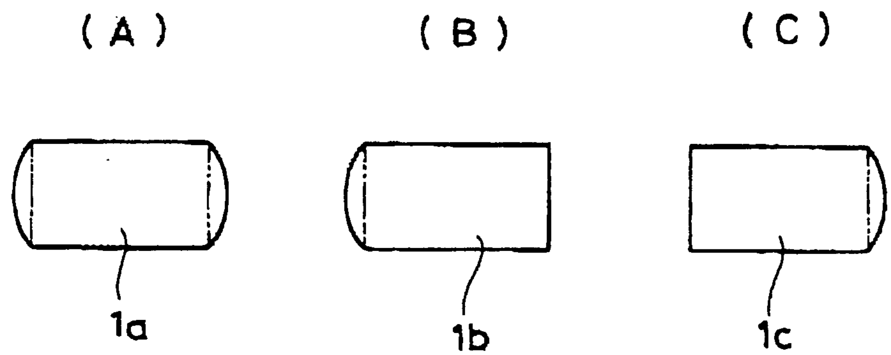

Z
5
4
7
1
2
3

FIG. 5



[Name of document] Abstract

[Abstract]

[Problem] To more shorten the overall length of an image pickup device comprising a lens and an image pickup element, and reduce the error of the positional relationship between the lens and the image pickup element.

[Means for Resolution]

A single refractive index distribution lens 1 having a refractive index distribution which is substantially proportional to the square of the distance from an optical axis 2 in a cross-section vertical to the optical axis 2 is provided as an imaging lens in the neighborhood of the imaging face 5 of an image pickup element 4. Specifically, the positional relationship between the image pickup element and the lens is fixed by adhesion of organic solvent 4 or the like. Further, an infrared-ray cut filter 6 is formed on the light incident face of the refractive index distribution lens 1.

[Selected Drawing] Fig. 1